BOLANDER'S CLOVER IN THE CENTRAL SIERRA NEVADA: A SENSITIVE SPECIES?

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ABSTRACT

Trifolium bolanderi Gray. (Fabaceae) is endemic to the central Sierra Nevada of California. Commonly called Bolander's clover, it is a federally designated Category 2 taxon for which sufficient data to support a listing as threatened or endangered are lacking. It occurs within a narrow elevational band in mountain meadows of Mariposa, Madera, and Fresno Counties. To learn more about Bolander's clover, its site characteristics, and its restricted distribution we surveyed all known populations. Concurrently, we examined adjacent sites without the species. Sites with Bolander's clover were like those without it in aspect and degree of shade and in soil texture, bulk density, water, and organic matter. Normal hydrologic regimes occurred on 93% of the Bolander's clover sites; and some, still grazed by livestock, had large clover populations. No plant taxa had a positive interspecific association with Bolander's clover. One species, another clover, was negatively associated with it, suggesting intrageneric competition as a controlling influence. Detailed research on nutrient requirements and availability and soil water relationships may point to characteristics restricting Bolander's clover distribution.

Sensitive plant and riparian area management are priority concerns of land managers. Within the state of California, 20% of 187 endangered, threatened, or rare native plants occur in moist or wet habitats (California Department of Fish and Game 1987). Eleven National Forests in California list 44 sensitive plants occurring in federally managed riparian/meadow ecosystems.

All species for which information is needed cannot be studied simultaneously, but knowledge gained by study of selected ones may facilitate research and management of similar species or those occupying similar habitats. This paper reports an initial effort on one species, a clover.

Bolander's clover, *Trifolium bolanderi* Gray. (Fabaceae) (Fig. 1) is endemic to meadows of the central Sierra Nevada in Yosemite National Park and the Sierra National Forest in California. The type location of Bolander's clover is Westfall Meadow in Yosemite, and it occurs within a narrow elevational band (2134 m to 2165 m) in Mariposa, Madera, and Fresno Counties (Jepson 1951). According to park and forest records, there are only 20 meadows with known populations (when this study started). The plant is glabrous, has reflexed flowers with lavender corollas, has decumbent or ascending stems (10- to 23-cm long) that are caespitose on a branched root-

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FIG. 1. *Trifolium bolanderi* Gray. (Bolander's clover).

crown (Jepson 1951, Munz 1970), and reproduces vegetatively as well as by seed.

Bolander's clover is designated by the U.S. Fish and Wildlife Service as a Category 2 taxon for which there is a lack of conclusive data to support a proposed listing as threatened or endangered, and it is categorized by The California Native Plant Society as a "list 4 species" which has limited distribution but low vulnerability (California Department of Fish and Game 1992). It is categorized as a "sensitive" plant species—rare, but found in sufficient numbers and distributed widely enough that, at this time, potential for extinction is low (Sierra National Forest 1991). Both the Sierra National Forest and Yosemite National Park maintain inventories of locations, and inventory data are cataloged by the Natural Diversity Data Base through the Natural Heritage Division of the California Department of Fish and Game.

There are no current plans to list Bolander's clover. Nevertheless, it occurs on grazed forest ranges, and its sensitive categorization may influence land use planning, even though little or no research has been done supporting its status determination, ecology, or response to management.

Given the lack of research, we do not know why Bolander's clover distribution is limited, whether its populations are declining or ex-

panding, and how best to manage land use in areas where it is subject to grazing disturbance.

Bolander's clover was selected for study because of the logistics of reaching meadows with known populations. Also, along with *Trifolium longipes* Nutt. (longstalk clover) and *T. monanthum* Gray. (carpet clover), Bolander's clover was expected to initially increase with overgrazing (Ratliff 1985). Observations related to that study suggested that Bolander's clover prefers wet sites on cool slopes where snow remains until late spring, but those observations also suggested that a shortage of such sites was not a limiting factor.

Logically, study of a species should start with learning about sites where it does and does not occur. Toward that objective and in hopes of identifying factors that limit the distribution of Bolander's clover and justify a sensitive categorization, we surveyed meadow sites with and without that species.

Methods

From late May through August 1990 we surveyed 69 sites in the 20 meadows known to have Bolander's clover and 12 sites with that species in meadows where it had not previously been reported. Adjacent sites in the same meadows but without Bolander's clover were also surveyed. In all, sites in 32 meadows were studied: 10 meadows were protected from livestock grazing in Yosemite National Park, and 22 meadows were subject to grazing on the Sierra National Forest.

Sampling. Meadow hydrology and the influence of grazing largely determine botanical composition, and with aspect, shade, and elevation may serve as key indicators defining ecological sites where Bolander's clover can occur. Aspect, shade, hydrology, and elevation were recorded for sites with Bolander's clover to question the earlier observation that it prefers cool wet sites. Also, the number of Bolander's clover plants was subjectively assessed, and whether the meadow was subject to grazing by livestock was noted. Sites with low shade received sun all day, those with moderate shade received sun from about 9 a.m. to 4 p.m., and those with heavy shade received sun from about 10 a.m. to 2 or 3 p.m. Hydrology evaluations followed the six meadow hydrologic classes of Ratliff (1985). Those classes were: Raised-convex—a site (with an enclosed open water surface) occurring as a mound above the surrounding meadow; hanging—a site that occurs on a slope and is constantly watered by flows from springs and seeps; normal—a site that obtains water from the water table, is recharged by precipitation, and may dry in the surface during summer; lotic—a site that is characterized by moving water and constantly watered by flows from upstream; xeric—a site that occurs on a slope or bench, is seasonally recharged by precipitation

and becomes quite dry during summer; and sunken-concave—a site that is characterized by ponded water and is seasonally recharged by flows from upstream.

At each site containing Bolander's clover, a single 40- × 40-cm quadrat was randomly located on the longest axis and near the site center. The quadrat was placed on the surface and then flipped over left or right depending on a coin toss, and a second paired quadrat was randomly placed left or right of the first on a site without Bolander's clover.

Within each quadrat all rooted species were recorded to determine patterns of interspecific association. At a fixed point on each quadrat frame hits on litter, moss, plants, and bare soil were recorded to learn if major differences occurred in soil surface characteristics between quadrats with and without Bolander's clover.

Soil classification contributes to the definition of an ecological site. Most meadow soils do not have pedogenic horizons, however. Consequently, the 0- to 20-cm depth has been used as a standard for classifying and comparing meadow sites (Ratliff 1985). Near the center of each quadrat, readings of soil temperature were taken at depths of 5 cm and 10 cm. A small-diameter (1.9 cm) core (volume = 48.5 cm^3) was extracted from a depth of 0 cm to 17 cm for determination of soil water and bulk density. The cores were sealed in cans, and wet and oven-dry (105°C for 48 hours) weights were estimated in the laboratory. A large-diameter (5.1 cm) core was collected from the same depth to estimate soil texture and organic matter content. Soil separates were analyzed by the hydrometer method (Bouyoucos 1936). Organic matter content was estimated by weight loss after 6 hours at 600°C.

Statistical analyses. The hypothesis that the numbers of sites with Bolander's clover having different aspects, shade levels, and hydrology were equal was tested by Chi-square with $\alpha = 0.05$. The hypothesis of equal proportions of quadrats with and without Bolander's clover having a particular species or surface characteristic was rejected when the 95% confidence interval for the difference in proportions failed to cover zero (Dixon and Massey 1957). The hypothesis that the difference in a soil property between quadrats with and without Bolander's clover was zero was tested by paired t-test with $\alpha = 0.05$.

Results

Site characteristics. We found the species in meadows from 2073 m to 2226 m elevation.

The 81 sites with Bolander's clover did not occur in equal numbers on all aspects ($\chi^2 = 26.4$, with 4 df). The majority of sites occurred on flat (33%) and south (31%) aspects. Occurrence on north-facing

aspects was 23%, and east and west aspects together comprised about 13% of the sites.

Degree of shading during the day was statistically unrelated to the number of Bolander's clover sites ($\chi^2 = 4.1$, with 2 df). Nevertheless, 42% were in low shade, 35% were in moderate shade, and 23% were in heavy shade.

Bolander's clover appears to favor sites of the "normal" meadow hydrologic class (Ratliff 1985). Ninety-three percent of the sites with Bolander's clover—far more than expected by chance ($\chi^2 = 171.9$ with 3 df)—occurred under that hydrologic regime. Hanging (3%), lotic (3%), and xeric (1%) sites comprised the remainder.

Plant numbers were estimated to vary from less than a hundred to several hundred thousand. Nearly half of the sites were characterized by populations numbering in the 1000's.

Associated species. Positive association between species may exist when they are favored by similar abiotic and/or biotic factors of the habitat but their resource requirements are not competing. Among 43 species reported, none occurred on a higher proportion of quadrats with Bolander's clover than without it than was expected by chance. Negative association may exist when species are found in the same quadrat less often than expected. Only one species, longstalk clover, occurred on a significantly greater proportion (40% vs. 20%) of quadrats without Bolander's clover than on quadrats with it (Table 1). These results suggest that Bolander's clover is not associated with a particular species or group of species, apart from other meadow species. While Bolander's and longstalk clovers may occur in the same quadrat, their indicated association was negative.

No major differences were found in surface characteristics between quadrats with and without Bolander's clover. The proportion of quadrat pairs with hits on the same surface characteristic (70.8%) was greater than expected by chance. Average percentages of surface characteristics over all quadrats were: litter, 10.4%; moss, 12.5%; plants, 62.5%; and bare soil, 14.6%.

Soil properties. The soil properties examined did not differ significantly between quadrats with and without Bolander's clover (Table 2). Soil textures were sandy loams—the average for meadow soils over a large part of the Sierra Nevada (Ratliff 1985). Organic matter content was also about average for the depth range sampled.

Discussion and Conclusions

The suggestion that Bolander's clover prefers wet sites on cool slopes (hanging hydrology) with long-lasting snow cover was not substantiated by the known population. Rather, Bolander's clover occurred with 4 hydrologic classes, primarily, the normal class.

TABLE 1. OCCURRENCE OF 15 SPECIES OR GROUPS IN QUADRATS WITH AND WITHOUT BOLANDER'S CLOVER IN THE CENTRAL SIERRA NEVADA. Number of quadrat pairs = 81, and quadrat size = 40 cm × 40 cm. * Significantly different (P = 0.95) from quadrats with Bolander's clover.

Species	Number of quadrats	
	With	Without
Carex nebraskensis Dewey.	27	30
C. species L.	29	30
Eleocharis pauciflora (Lightf.) Link.	11	16
Grass species	5	10
Hypericum anagalloides Cham. & Schlecht.	19	17
Ivesia unguiculata Gray.	10	8
Juncus oxymeris Engelm.	13	15
Mimulus primuloides Benth.	42	44
Muhlenbergia filiformis (Thurb.) Rydb.	7	6
Perideridia bolanderi (Gray.) Nels. & Macbr.	8	5
Phalacroseris bolanderi Gray.	11	15
Polygonum bistortoides Pursh.	17	22
Trifolium longipes Nutt.	16	32*
Trifolium monanthum Gray.	5	9
Viola macloskeyi Lloyd.	16	20

Bolander's clover occurs in meadows grazed by livestock for over 100 years and in meadows ungrazed for at least that long. A tendency toward a more decumbent growth habit was observed and the smallest populations (less than 100 plants) occurred on grazed sites. Nevertheless, where grazing use appeared to be moderate, the populations were healthy, and sites with the largest populations (10,000 plants or more) all occurred on grazed meadows. As a management option, therefore, total protection from livestock grazing does not appear necessary. A study of morphological and physiological re-

TABLE 2. SOIL PROPERTIES OF QUADRATS WITH AND WITHOUT BOLANDER'S CLOVER IN THE CENTRAL SIERRA NEVADA. Number of quadrat pairs = 81, and quadrat size = 40 cm × 40 cm. * 95% confidence interval of the difference by paired t-test.

Property	Quadrats		Difference*
	With	Without	
Texture	Sandy loam	Sandy loam	
Sand (%)	61.7	62.8	−1.11 ± 1.90
Silt (%)	31.3	30.5	0.82 ± 1.67
Clay (%)	7.0	6.7	0.30 ± 1.04
Temperature (°C)			
5-cm depth	15.2	15.1	0.11 ± 0.30
10-cm depth	14.6	14.4	0.17 ± 0.23
Water (%)	69.6	72.2	−2.57 ± 7.65
Organic matter (%)	15.3	16.1	−0.85 ± 1.81
Bulk density (g/cm^3)	0.89	0.88	0.01 ± 0.05

sponses to defoliation will be needed in order to evaluate hypothetical responses to frequency and season of livestock grazing.

This study failed to reveal biological reasons for the limited distribution of Bolander's clover. It was not associated with any one species or species group which might tie it to a specific association. The indicated negative association of Bolander's clover and longstalk clover may result from the two species occupying similar ecological niches.

Bolander's clover occurred under varied environmental situations, even near the type location in Yosemite National Park, and meadow sites with it did not appear to possess unique characteristics. Their soils and other abiotic factors were representative of many meadow sites in the central Sierra Nevada; elevation remains the only identified unique parameter. We thus hypothesize that Bolander's clover has a high ecological amplitude with regard to environmental variables.

Differences between sites with and without Bolander's clover may be quite subtle, however, and thereby have escaped detection. A more detailed analysis of plant community structure and hydrologic regimes and analysis of nutrient requirements and availability and soil pH, therefore, may reveal why Bolander's clover has restricted distribution.

We found 37.5% of the 32 meadows known to contain populations of Bolander's clover, during this study. Given our present state of knowledge, the meadows themselves are likely more sensitive than Bolander's clover. Constancy of hydrology is a key determinant of plant species in meadows (Allen-Diaz 1991; Hormay 1943). Therefore, we suggest that maintaining the ecological integrity of the meadows through appropriate management will maintain viable populations of Bolander's clover. Managers should strive to keep the sod intact and, thereby, prevent accelerated erosion and preserve meadow hydrologic regimes.

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ANNOUNCEMENT

Southwest Botanical Systematics Symposium

The Ninth Annual Southwestern Botanical Systematics Symposium will be held May 28–29. This year's topic is "Plant Reproductive Biology." Invited speakers include William L. Crepet, Cornell University; W. Scott Armbruster, University of Alaska; John F. Addicott, University of Alberta; Elizabeth M. Lord, University of California, Riverside; Allison Snow, Ohio State University, C. Thomas Philbrick, Rancho Santa Ana Botanic Garden. The evening address will be given by Robert Ornduff, University of California, Berkeley.

The cost to attend is $50.00 per participant ($45.00 per student). This includes the Friday evening social, continental breakfast, boxed lunch, and banquet dinner on Saturday. To register, send your name, address, and telephone or Fax number, with a check for the proper amount payable to Rancho Santa Ana Botanical Garden. Mail these to the following address: RSABG, Systematics Symposium, 1500 North College Avenue, Claremont, California 91711. There will be no refunds after May 14, 1993. For more information, please call (909) 625-8767, ext. 251. Be sure to register early as space is limited.